AMP NETCONNECT

XG SHIELDED COPPER SYSTEM

The Complete High-Performance, Cost-Effective Twisted-pair Premises Cabling Solution for Supporting Ten Gigabit Networks

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PERSPECTIVE

In less than ten years, LAN performance levels evolved from 10 Mbps Ethernet (10BASE-T) and 16 Mbps token ring to Fast Ethernet (100BASE-T) Ethernet and 155 Mbps ATM. Concurrently, twisted-pair cabling system performance advanced from Category 3 through Category 4 to Category 5 to accommodate these applications. The subsequent evolution of both Gigabit Ethernet (1000BASE-T) and a cabling standard for Enhanced Category 5 (Category 5e) demonstrated the need to improve cabling performance in order to accommodate new applications. While Category 5e offers only a relatively minor improvement in performance over Category 5, new parameters and measurements were defined for Category 5e specifically to support the Gigabit Ethernet application. Shortly thereafter, a cabling standard for Category 6 was completed defining even more parameters and measurements that enabled a lower-cost variant of Gigabit Ethernet (1000BASE-TX). So, the history of tying twisted-pair cabling categories to new evolutions in LAN applications is firmly established.

So it is again with the IEEE 10 Gigabit Ethernet (10GBASE) Standards. Although there were initially several proposals to enable a copper-based PHY, the original 10GBASE Standard (802.3ae) recognized only optical fiber options, including a new 50-micron multimode fiber (850nm laser-optimized 50/125µm), as acceptable media (for more information on this, see the white paper entitled "*AMP NETCONNECT XG OPTICAL FIBER SYSTEM: The Complete High-Performance, Cost-Effective Optical Fiber Premises Cabling Solution for Supporting Ten Gigabit Networks*").

Now, after almost three years of work, the IEEE has defined a 10GBASE Standard on balanced (twisted-pair) cabling, the 10GBASE-T Standard (802.3an). During this process, there were several issues identified related to 10 Gigabit applications and structured cabling systems. There was also a continual stream of new product announcements and performance claims in the market for 10-gigabit twisted-pair products. Trying to make sense of the claims, evaluate them on an even playing field, and selecting the best choice makes for an interesting challenge to say the least. This white paper presents the facts and provides the necessary information to simplify this challenge for 10-gigabit network cabling.

WHY EVEN WORRY ABOUT 10 GIGABIT?

To end users, the answer is simple: no one wants to wait – time is too valuable. All of that e-mail, those graphic-intensive multimedia files, videos, audio files, web conferences and web page downloads should fly through the network fast enough that each user feels as if he or she is on a real-time, no-delay, dedicated connection to the LAN. To the administrator, this need for speed equates to providing faster and faster data rates – more bandwidth. Data rates implemented on horizontal cabling systems have grown from 10 Mbps (megabits or millions of bits per second) to 100 Mbps, and to 1000 Mbps (or 1 *gigabit* per second) today. Tomorrow, there are even good arguments for 10 gigabit data rates in the horizontal.

WHAT THE INDUSTRY WANTS

In an ideal world, the migration to 10 Gigabit Ethernet would be seamless on a generic cabling system. That means the application would be able to run on existing UTP cabling infrastructures to the full 100 meters, but the 100m distance on existing twisted-pair media was too difficult.

THEY SOLVED IT FOR GIGABIT – THEY'LL SOLVE IT FOR 10 GIGABIT ...RIGHT?

Actually, it's not that simple. Even when they "solved" it for Gigabit, they still needed to redefine Category 5 cabling – that's why there is Category 5e cabling. Category 5, even good category 5, couldn't always get to 100 meters for 1 Gigabit Ethernet (1000BASE-T) in a four-connector channel. Even with Category 5e cabling, there was still a lot of digital signal processing required to compensate for the cross-talk and echo inside the cable. Category 6 cabling relieved some of the digital signal processing load so it can run a less-expensive variant of Gigabit Ethernet (1000BASE-TX), but this again required a new cable category – one that was even sold by some manufacturers as "future proof". The future came quickly,

and today it's recognized that even Category 6 is not sufficient for 10GBASE-T except at lengths shorter than 100m, and neither is Category 6 cabling with extra margin (like "Category 6e" products).

Why? Simply put, the higher symbol rate of 10GBASE-T requires a higher signal bandwidth of 500MHz. Category 5e (Class D), if used, will thus be utilized beyond its specified frequency range. Category 6 (Class E), likewise, will have to have its performance characterized beyond 250MHz.

A TECHNOLOGICAL FOUNDATION

Much of the early study, research and development focused on theoretical capacity of twisted-pair media. Claude Shannon, a Bell Labs scientist, developed a formula to determine the maximum capacity of a channel in a noisy environment...it's called Shannon's Law. Shannon's Law calculates the theoretical maximum amount of information that can be transmitted over a bandwidth-limited carrier in ever-present background noise. This is the formula.

$$C = W \cdot log_2(1 + S/N)$$

Where: C = bits per second (channel capacity, or "Shannon Capacity")

W = frequency (bandwidth)

S/N = signal-to-noise ratio

So, for a constant frequency, the capacity is basically determined by the signal-to-noise ratio (SNR). A higher SNR means more capacity; higher noise means less capacity. Solving the equation for the necessary bandwidth to support 10-gigabit data rates yields a Shannon Capacity between 18 and 22 Gigabits per second, depending on the assumptions for SNR. Now the challenge began to design a cabling system that could achieve this value.

Since there is a fine line between higher twist rates and higher attenuation, reducing the signal to noise

ratio became a primary focus of the effort. Noise compensation inside of a single cable for cross-talk and echo can be addressed through brute-force digital signal processing. At these 10-gigabit data rates using the faster encoding schemes, the radiated electrical noise (crosstalk) from other cables becomes problematic. This “alien” cross talk (Alien NEXT or ANEXT) cannot be sampled, nor even easily measured. So it is not easily compensated, unlike the internal pair-to-pair cross talk that created a problem for Gigabit Ethernet. Although there were many noise mitigation techniques proposed (some based on modifying installation practices such as increasing cable separation), the fact remains that alien NEXT cannot be directly cancelled.

Clearly, the solution must focus on three issues: increased bandwidth, adequate Shannon capacity and reduction of ANEXT.

SO...WHAT IS THE SOLUTION?

The required bandwidth is 500MHz for 10G cabling - well beyond the 200 MHz frequency requirement of Category 6. Fortunately, with manufacturing improvements and technological advancements in materials, this bandwidth can be obtained.

ANEXT can be mitigated by a grounded foil shield (as in shielded cable). The shield also reduces the alien crosstalk, making for an improved signal-to-noise ration and a larger Shannon capacity. This simple foil shield provides a shielded system with performance capabilities beyond that of any unshielded solution.

Unshielded solutions, without the benefit of the foil shield, have to mitigate ANEXT by spacing apart the cables and connectors to reduce the intensity of radiated noise, which decreases with the square of the distance from the source. Since it is difficult to keep cables separated once installed in bundles, increasing the cable diameter to 0.354 inches from 0.25 inches is part of the unshielded cabling solution.

TESTING SHANNON'S LAW

Before there was any standards-based testing or standards-based requirements for that matter, Tyco Electronics conducted internal testing on shielded and unshielded cabling products. To generate noise for the channel under test, six cables were placed around the cable under test for a length of 100m – this is an effective model for a worst-case situation of an installed cabling system, as six disturbing cables around one provides the greatest noise at all points of the cable through the full length.

TESTING SHANNON'S LAW – SHIELDED TWISTED PAIR

A test channel constructed with seven shielded Category 6 cables (cables with a four-pair Category 6 bundle wrapped in a foil shield and jacketed, also known as an "F/UTP" construction) was tested against numerous variations in input parameters that were likely to represent the final IEEE parameters. In all cases the Shannon capacity was well above 18 Gb/s and in some cases was as high as 24 Gb/s.

This testing validated F/UTP solutions as sufficiently capable of handling a 10-gigabit application and justified the IEEE inclusion of this cable as a selected media in the 802.3an Standard.

TESTING SHANNON'S LAW – UNSHIELDED TWISTED PAIR

Using a similar setup, an unshielded Category 6 standards-compliant 100m channel was tested. In these tests, the Shannon Capacity for unshielded twisted pair systems was right around 10Gb/s, but in some cases as low as 9.8 Gb/s. So, while theory holds that the cable performance might be sufficient, there is little margin for error and little margin for real-world conditions.

This basically means that the noise becomes the significant factor for an unshielded solution. Even a bandwidth increase and additional noise cancellation are not enough to overcome its influence. This testing justified the significant reduction in the supportable distance of 10-gigabit applications on

Category 6 cabling. Thus, the bottom line is that unshielded Category 6 cabling had to be improved to overcome alien cross-talk and be able to support 10GbE to the expected horizontal distance.

SHANNON'S LAW – CONCLUSIONS

This testing became a good representation of system performance. Clearly, shielded cables (both F/UTP and PiMF, or F/FTP) have roughly the same Shannon Capacity and, even with conservative assumptions, both are sufficient for 10Gb/s and were cabling options included in the IEEE standard. Standard unshielded Category 6 cabling, or even "enhanced" Cat 6 with NEXT headroom, does not have sufficient Shannon Capacity for 10GbE to 100m, and thus a new type of unshielded cable, Augmented Category 6 Unshielded twisted-pair cabling, was developed.

AUGMENTED CATEGORY 6 (CATEGORY 6a)

To achieve the 100 meter distance for 10GBASE-T, TIA started to work on an addendum for Augmented Category 6. During this effort, it became clear that the limits for unshielded twisted-pair cabling would be very tight and, to reduce ANEXT, the cables would have to get bigger and the connectors would have to be separated. The development of this addendum was quite contentious due to the very slim margin between the necessary performance of unshielded cabling and the capabilities of an unshielded cabling system.

10G TODAY

If migration to 10 GbE is a consideration for a network installation today, and it should be, there are three options. Optical fiber provides a proven, available and cost-effective solution that will support standards-

based structured cabling networks and offer extra distance. There is little doubt that the shielded twisted-pair systems will offer the necessary bandwidth and performance to support 10 Gigabit Ethernet to 100 meters. An unshielded augmented category 6 solution has been created to stretch the limits of unshielded cabling to 100 meters of 10 gigabit.

However, unshielded category 6, as it is currently defined, will support 10 GbE only to some shorter distance without mitigation techniques to reduce the influence of ANEXT.

IEEE has turned a lot of effort, research, development, testing, debate and confusion into a Standard published in July 2006. TIA has two related documents on the cabling that is based on their consensus.

HOW IS TYCO ELECTRONICS SOLVING THE PROBLEM?

Tyco Electronics is determined to offer our customers solid, standards-based solutions. That's why the **AMP NETCONNECT XG Shielded Copper Cabling System** was released. The XG Shielded Copper Cabling System offers the best combination of shielding, Shannon Capacity and bandwidth to ensure this cabling solution will meet the needs of the 10 Gigabit Ethernet application.

This solution, coupled with the AMP NETCONNECT SL Series Installation Tool enables quick, efficient and effective installation of shielded networks. Unshielded cabling is no longer the lowest-cost, easiest-to-install, equivalent application support solution. Performance and innovation make the **AMP NETCONNECT XG Shielded Copper Cabling System** the best choice for 10 Gigabit Ethernet twisted-pair cabling.

WHY SHIELDING, SHANNON CAPACITY AND BANDWIDTH?

The answer is simple, it takes all three. Simply adding a foil shield to a category 6 cable is insufficient – although it goes a long way to solve ANEXT issues. Similarly, a high Shannon Capacity (18-22 Gb/s) is good, but alone will not determine a cabling system's ability to support 10GbE in the real world, and

neither will a high bandwidth (500 MHz or more).

So, a reasonable, conservative approach argues for all three, and that's just what the **AMP NETCONNECT XG Shielded Copper System** provides: shielding, a Shannon Capacity greater than 25 Gb/s and a bandwidth higher than 500 MHz.

WHAT ABOUT AN UNSHIELDED SYSTEM SOLUTION?

The marginal performance of even the best unshielded solution for 10GbE has been evident in all of the standards bodies. While the cable performance limits seemed to be stable early in the process, the refinement needed in measurement methods and field testing delayed the TIA efforts well past the conclusion in IEEE. Thus, Tyco Electronics is offering the AMP NETCONNECT XG Shielded Copper System as the best copper option for 10GbE.

CONCLUSIONS

Educated consumers are the best customers for Tyco Electronics. Since Tyco Electronics has complete shielded twisted-pair, unshielded twisted-pair and optical fiber cabling products for 10-gigabit networks, our **AMP NECONNECT XG Cabling Systems** are the best choice regardless of your cabling media choice.

The **AMP NETCONNECT XG Shielded Copper System** offers the best performance and cost/benefit balance for 10GBASE-T solutions. Similarly, optical fiber offers a great solution today for your 10 GbE applications of tomorrow.

Although the end-user comfort level for U/UTP solutions is high in North America, the cost, space and performance benefits traditionally associated with unshielded twisted-pair cabling have now flipped in favor of shielded systems. So, unshielded twisted-pair media may be the traditional choice but one that

may be harder to justify.

When considering the network cabling options that are available, it may help to consider each segment of the network individually. Just as most installations today use optical fiber in the backbone and twisted pair in the horizontal, it may make sense to combine two or more media types (fiber, shielded twisted-pair and unshielded twisted-pair) rather than make the decision on an “all-for-one” basis.

Count on Tyco Electronics, an active participant and leader in the industry and standards to keep you informed. You can count on Tyco Electronics to offer sound advice, knowledgeable comparisons, and provide quality products. Regardless of your choice of cabling media, there is one answer: Tyco Electronics.